MVP Data Processing Notes – 2015 Leg1

Last updated on 28 July 2015

NGCC • CCGS

AMUNDSEN

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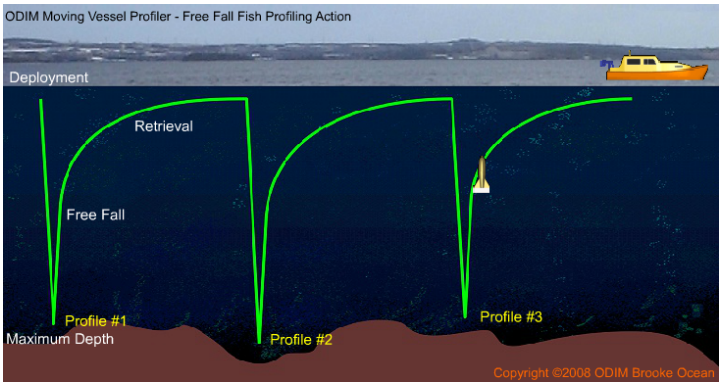
1. Introduction

The Canadian research icebreaker CCGS *Amundsen* is equipped with a Moving Vessel Profiler™ (MVP). It is a multi-purpose instrument for aiding in the collection of both shallow and deep-water datasets. The MVP's primary function is to allow accurate data collection without the need to stop the vessel.

The system includes a computer-controlled smart winch and deployment system that allows the free fall fish to be deployed while the vessel is underway.

The fish is equipped with several sensors to record data on temperature, salinity, Fluorescence, sound velocity, dissolved oxygen and transmittance.



Down cast (free fall) and up cast (low recovery)

Winch operation

Fish (sensors platform)

Table 1: Instruments and probes

Instrument	Company	Unit	Serial number	Calibration date
Temperature	AML	°C	7416	2015-01
Conductivity	AML	mS/cm	7416	2015-01
Pressure	AML	Db	7416	2015-01
Sound velocity	AML	m/s	7417	2015-01
Pressure	AML	db	7417	2015-01
Dissolved Oxygen	AML	%	7439	2015-04-01
Fluorescence	WetLabs	ug/L	FLRTD-678	2014-12-17
Transmittance	WetLabs	%	1049DR	2014-12-18

Table 2: Recorded variables

Instrument	Company	Measurement	Specification	
Micro CTD	AML	Temperature	Range (°C)	-2 to +32
			Initial Accuracy (°C)	0.005
			Resolution (°C)	0.001
		Conductivity	Range (mS/cm)	2 to 70
			Initial Accuracy (mS/cm)	0.01
			Resolution (mS/cm)	0.0015
		Pressure	Range (m)	0 to 6000
			Initial Accuracy (%FS)	0.05
			Resolution (%FS)	0.005
Micro SV	AML	Sound velocity	Range (m/s)	1375 to 1600
			Initial Accuracy (m/s)	0.05
			Resolution (m/s)	0.01
		Pressure	Range (m)	0 to 6000
			Initial Accuracy (%FS)	0.05
			Resolution (%FS)	0.005
Micro DO2	AML	Dissolved	Range (%)	0-100
		Oxygen	Response time (s)	>3
			Drift (%/month)	5
ECOFLO	WetLabs	Fluorescence	Range (ug/L)	0 to 125
			Sensitivity (ug/L)	0.062
			Wave length (nm)	470/695
C-Stars	WetLabs	Transmittance	Range (%)	0 to 100
			Path length (cm)	25

2. Processing protocol

The following treatment steps were performed using the script:
Processing_Amundsen_MVP.m developed in Matlab in Amundsen Science offices.

A: Data reading

A1: Read TSG data

From processed TSG data (files *.int, see TSG processing report by the Amundsen Science technical team).

A2: Read CTD rosette data

From processed Rosette data (files *.int, see Rosette processing report by the Amundsen Science technical team).

A3: Read MVP data

From MVP raw data (files *.raw).

B: Flag and processing

The processing steps in section B are sequentially applied on each cast of a given MVP transect.

B.1: Calibration of the analogic inputs

MVP data from the transmissometer, fluorimeter and dissolved oxygen sensors are recorded in volts 0-5V. Calibration coefficients are applied in post processing to transform the volt values into the recognised units for these recorded variables. Calibration dates are given in table 1.

B.2: Averaging pressure

The SVP and CTD sensors both record pressure. Data from the two datasets are averaged to improve the accuracy of the variable.

B.3: Low pass filter (SBE data processing toolbox)

A Low pass filter is applied on the temperature, conductivity, sound velocity, transmittance, fluorescence and dissolved oxygen time series data. The time constant is fixed at 0.2s to keep the accuracy of the measure and allow for further filtering on averaged bin performed in B.8. For instance, with a free fall at ~3m/s, the filter does not affect a depth gap of one meter (3x0.2=0.6m).

B.4: Align sensor filter (SBE data processing toolbox)

The temperature and conductivity sensors do not have the same response time. This filter aligns data parameters by time, relative to pressure. This ensures that calculations of salinity and other derived parameters are made using measurements from the same parcel of water. The time-offset corrections are the following:

- Temperature: + 0.200s
- Conductivity: + 0.025s

The comparison with and without the Low pass filter and Align sensor filter is presented in annex 5.

B.5: Loop edit filter (SBE data processing toolbox)

The Loop edit processing tests the data for pressure slowdowns and reversals (typically caused by ship heave). It flags scans that fail these tests. Loop edit filter marks also scans associated with an initial surface soak.

The thresholds for the tests are:

- Minimum velocity: 0.25m/s
- Surface soak depth: 8m
- Minimum soak depth: 5m
- Maximum soak depth: 20m

B.6: Flag out-of-range values

For pressure, latitude and longitude, temperature, conductivity, sound velocity, transmittance, fluorescence and dissolved oxygen values, the flag checks if the values are not out of range (see thresholds in section 3 “Processing characteristics”).

B.7: Flag of spiking values

For each measurement (temperature, conductivity, sound velocity, transmittance, fluorescence and dissolved oxygen), the flag checks spiking values (see thresholds in section 3 “Processing characteristics”) as follows:

$|V2 – (V3 + V1) / 2| - |V1 –V3| / 2 >$ threshold, where V1, V2 and V3 are 3 consecutive values.

B.8: Bin average filter (SBE data processing toolbox)

The Bin average filter averages data using intervals based on pressure ranges. The bin sizes are fixed at one meter.

B.9: Calculation of the derived parameters

These calculations use pressure, temperature, and conductivity data to compute the following oceanographic parameters: salinity, sound velocity, density, freezing point, depth and DO2 saturation (sea water toolbox V3.2 from CSIRO).

B.10: Manual data check

A graphic toolbox allows the analyst to check, compare and flag the measurements for the following variables:

- Temperature profile: down cast, up cast and freezing point
- Salinity profile: both down and up casts
- Sound velocity profile: both down and up casts from measurements and down cast from derived value (calculated from pressure, salinity and temperature)
- Transmittance: both down and up casts
- Fluorescence: both down and up casts
- Dissolved oxygen: both down and up casts
- Density: both down and up casts
- d(density)/d(pressure): both down cast and up casts

See example in annex 6.

C: Correction and inter-comparison

The processing steps described in section C are applied on each MVP transect.

C.1: Transmittance maximum adjustment

Transmittance values of each MVP cast are adjusted with the transect maximum transmittance as follows:

Vcorrected = Vmeasured + (100-maximum).

C.2: Fluorescence minimum adjustment

The minimum fluorescence value for each MVP cast is determined. Then, the median of these minimum values is subtracted from fluorescence values of all casts:

Vcorrected = Vmeasured - minimum.

C.3: Dissolved oxygen adjustment

The data from the oxygen sensor collected during the MVP free fall (~4m/s) cannot be used in post-processing steps due to the slow time response of the sensor (>3s). To resolve this problem, the up cast measurements of oxygen are used. The up cast oxygen values are interpolated based on down cast pressure values, which is consistent with other post processing steps.

The oxygen sensor output also has a non-negligible drift with time. The calibration coefficients (measured before the cruise) are not sufficient to calibrate the sensor. A comparison with the oxygen sensor on the rosette is therefore required: the percentage of dissolved oxygen measured with the co-localised rosette is averaged between 150 and 250-meter depth. This value is then compared to the MVP up cast at the same depths and a constant error is calculated. This error adjustment is then applied on all MVP casts for all depths of each transect.

C.4: Rosette inter-comparison

- All rosettes done between 24 hours before the first cast and 24 hours after the last cast of the transect are detected.
- Each of these rosettes is associated to the nearest MVP cast for variables inter-comparison (rejected if the distance is greater than 10.8NM – Nautical Mile).
- The variable of each MVP profile are then plotted (down casts) with the profiles of the bordering rosette. In addition, mean and standard deviation of all MVP down cast profiles of each transect are plotted (for geographic variability visualisation). See plot for this leg in annex 1.

C.5: TSG inter-comparison

- The first 10 meters of MVP salinity and fluorescence records are averaged for each down cast and each up cast.
- TSG data are co-localised and averaged on 2 minutes
- Differences (MVP-TSG) are flagged if:
    1- MVP vertical standard deviation (on first 10 meter) > threshold
    2- TSG time series standard deviation (on 2 minutes) > threshold
    3- Difference > median (differences) +/- standard deviation (differences).
- Remaining differences (not flagged) are plotted and then a constant is selected and applied on all casts (for salinity and fluorescence).

See annex 2 for graph and section 3 Processing characteristics for thresholds.

D: Final data format

Data profiles (down cast profiles only, excepted dissolved oxygen data) are saved in text format with the extension *.int. One folder per MVP transects and one file per cast are created.

Table 3: Data file format

Col	Content	Format	Units
1	Pressure	F12.2	dB
2	Temperature (ITS-90)	F12.2	deg C
3	Practical Salinity	F12.2	psu
4	Sound velocity	F12.2	m/s
5	Transmittance	F12.2	%
6	Fluorescence	F12.2	ug/L
7	Dissolved Oxygen	F12.2	mL/L
8	Absolute Salinity (TEOS-10)	F12.2	g/kg
9	Conservative Temperature (TEOS-10)	F12.2	deg C
10	In situ density (TEOS-10)	F12.2	kg/m^3
11	Potential density (TEOS-10)	F12.2	kg/m^3

NaN stands for: Not a Number. It indicates that no data was recorded or that the data was flagged and mistrusted.

3. Processing characteristics

This information is automatically generated from the processing program. The codes B6, C3, C5, etc. refer to the processing steps explained and detailed in the corresponding sections above. The Processing characteristics section provides the values for each parameter used during the treatments detailed in section B6, C3, C5, etc. Due to the absence of data, a treatment may not be applied.

3.1 Transect 1

Amundsen MVP data processing
Amundsen_2015001
Year: 2015
Leg: 1
Transect: 1
Processing date: 13-May-2015

////////// Limits and Thresholds Settings //////////
B6: -2.00 db - Minimum pressure
B6: 7000.00 db - Maximum pressure
B6: -3.00 °C - Minimum temperature
B6: 30.00 °C - Maximum temperature
B6: 0.00 mS/cm - Minimum conductivity
B6: 70.00 mS/cm - Maximum conductivity
B6: -0.10 ug/L - Minimum fluorescence
B6: 20.00 ug/L - Maximum fluorescence
B6: 1400.00 m/s - Minimum sound velocity
B6: 1500.00 m/s - Maximum sound velocity
B6: 0.00 % - Minimum dissolved oxygen
B6: 100.00 % - Maximum dissolved oxygen
B6: 0.00 % - Minimum transmittance
B6: 120.00 % - Maximum transmittance
B7: 0.40 °C/m - Temperature limit spike
B7: 0.20 mS/cm - Conductivity limit spike
B7: 4.00 m/s/m - Sound velocity limit spike
B7: 4.00 %/m - Transmittance limit spike
B7: 10.00 ml/L/m - Dissolved oxygen limit spike
B7: 10.00 ml/L/m - Fluorescence limit spike
C5: 10.00 m - Lower depth for comparison MVP-TSG

C5: 0.02 psu - Standard deviation flags on MVP salinity at several depths for comparison MVP-TSG

C5: 0.20 ug/L - Standard deviation flags on MVP fluorescence at several depths for comparison MVP-TSG

C5: 0.04 psu - Standard deviation flags on TSG salinity during 2 minutes for comparison MVP-TSG

C5: 0.05 ug/L - Standard deviation flags on TSG fluorescence during 2 minutes for comparison MVP-TSG

////////// Processing //////////

------ Inter-comparison------

C1: Bias applied on transmittance

Constant bias correction: -9.100 %

C2: Bias applied on fluorescence

Constant bias correction: -0.265 ug/l

C3: Bias applied on dissolved oxygen

Constant bias correction: -16.142%

C5: Salinity bias statistics

Number of samples used (TSG) = 2

Median (bias)= -0.021

Mean (bias)= -0.021

Standard deviation (bias)= 0.006

Accuracy (bias)= 0.004

C5: Fluorescence bias statistics

Number of samples used (TSG) = 0

Median (bias)= NaN

Mean (bias)= NaN

Standard deviation (bias)= NaN

Accuracy (bias)= NaN

C5: Bias applied on salinity

Constant bias correction: 0.000 psu

C5: Bias applied on Fluorescence

Constant bias correction: 0.000 ug/L

////// List of Casts //////

Cast	File_name	Date	Hour
1	1501001_0001.raw	18-Apr-2015	16:19:26
2	1501001_0002.raw	18-Apr-2015	16:30:04
3	1501001_0004.raw	18-Apr-2015	16:34:36
4	1501001_0006.raw	18-Apr-2015	16:39:24
5	1501001_0007.raw	18-Apr-2015	16:40:27
6	1501001_0008.raw	18-Apr-2015	16:41:30

3.2 Transect 2

Amundsen MVP data processing
Amundsen_2015001
Year: 2015
Leg: 1
Transect: 2
Processing date: 19-May-2015

////////// Limits and Thresholds Settings //////////
B6: -2.00 db - Minimum pressure
B6: 7000.00 db - Maximum pressure
B6: -3.00 °C - Minimum temperature
B6: 30.00 °C - Maximum temperature
B6: 0.00 mS/cm - Minimum conductivity
B6: 70.00 mS/cm - Maximum conductivity
B6: -0.10 ug/L - Minimum fluorescence
B6: 20.00 ug/L - Maximum fluorescence
B6: 1400.00 m/s - Minimum sound velocity
B6: 1500.00 m/s - Maximum sound velocity
B6: 0.00 % - Minimum dissolved oxygen
B6: 100.00 % - Maximum dissolved oxygen
B6: 0.00 % - Minimum transmittance
B6: 120.00 % - Maximum transmittance

B7: 0.40 °C/m - Temperature limit spike
B7: 0.20 mS/cm - Conductivity limit spike
B7: 4.00 m/s/m - Sound velocity limit spike
B7: 4.00 %/m - Transmittance limit spike
B7: 10.00 ml/L/m - Dissolved oxygen limit spike
B7: 10.00 ml/L/m - Fluorescence limit spike
C5: 10.00 m - Lower depth for comparison MVP-TSG
C5: 0.02 psu - Standard deviation flags on MVP salinity at several depths for comparison MVP-TSG
C5: 0.20 ug/L - Standard deviation flags on MVP fluorescence at several depths for comparison MVP-TSG
C5: 0.04 psu - Standard deviation flags on TSG salinity during 2 minutes for comparison MVP-TSG
C5: 0.05 ug/L - Standard deviation flags on TSG fluorescence during 2 minutes for comparison MVP-TSG

////////// Processing //////////
------ Inter-comparison------
C1: Bias applied on transmittance
Constant bias correction: -15.700 %
C2: Bias applied on fluorescence
Constant bias correction: -2.820 ug/l
C3: Bias applied on dissolved oxygen
Constant bias correction: 0.000%
C5: Salinity bias statistics
Number of samples used (TSG) = 16
Median (bias)= -0.023
Mean (bias)= -0.022
Standard deviation (bias)= 0.012
Accuracy (bias)= 0.003
C5: Fluorescence bias statistics
Number of samples used (TSG) = 13
Median (bias)= 0.067
Mean (bias)= 0.078
standard deviation (bias)= 0.136
Accuracy (bias)= 0.038
C5: Bias applied on salinity

Constant bias correction: 0.000 psu

C5: Bias applied on fluorescence

Constant bias correction: 0.000 ug/L

////// List of Casts //////

Cast	File_name	Date	Hour
1	1501002_0001.raw	01-May-2015	12:39:21
2	1501002_0003.raw	01-May-2015	12:42:26
3	1501002_0004.raw	01-May-2015	12:44:15
4	1501002_0005.raw	01-May-2015	12:45:24
5	1501002_0006.raw	01-May-2015	12:46:38
6	1501002_0007.raw	01-May-2015	12:47:40
7	1501002_0008.raw	01-May-2015	12:48:51
8	1501002_0009.raw	01-May-2015	12:50:00
9	1501002_0010.raw	01-May-2015	12:52:30
10	1501002_0011.raw	01-May-2015	12:54:05
11	1501002_0012.raw	01-May-2015	12:55:26
12	1501002_0013.raw	01-May-2015	12:56:47
13	1501002_0014.raw	01-May-2015	12:59:02
14	1501002_0015.raw	01-May-2015	13:00:25
15	1501002_0016.raw	01-May-2015	13:01:45
16	1501002_0017.raw	01-May-2015	13:03:21
17	1501002_0018.raw	01-May-2015	13:04:47
18	1501002_0019.raw	01-May-2015	13:06:06
19	1501002_0020.raw	01-May-2015	13:07:36
20	1501002_0021.raw	01-May-2015	13:08:55
21	1501002_0022.raw	01-May-2015	13:10:17
22	1501002_0023.raw	01-May-2015	13:11:37
23	1501002_0024.raw	01-May-2015	13:12:58

3.2 Transect 3

Amundsen MVP data processing

Amundsen_2015001

Year: 2015

Leg: 1

Transect: 3

Processing date: 13-May-2015

////////// Limits and Thresholds Settings //////////
B6: -2.00 db - Minimum pressure
B6: 7000.00 db - Maximum pressure
B6: -3.00 °C - Minimum temperature
B6: 30.00 °C - Maximum temperature
B6: 0.00 mS/cm - Minimum conductivity
B6: 70.00 mS/cm - Maximum conductivity
B6: -0.10 ug/L - Minimum fluorescence
B6: 20.00 ug/L - Maximum fluorescence
B6: 1400.00 m/s - Minimum sound velocity
B6: 1500.00 m/s - Maximum sound velocity
B6: 0.00 % - Minimum dissolved oxygen
B6: 100.00 % - Maximum dissolved oxygen
B6: 0.00 % - Minimum transmittance
B6: 120.00 % - Maximum transmittance
B7: 0.40 °C/m - Temperature limit spike
B7: 0.20 mS/cm - Conductivity limit spike
B7: 4.00 m/s/m - Sound velocity limit spike
B7: 4.00 %/m - Transmittance limit spike
B7: 10.00 ml/L/m - Dissolved oxygen limit spike
B7: 10.00 ml/L/m - Fluorescence limit spike
C5: 10.00 m - Lower depth for comparison MVP-TSG
C5: 0.02 psu - Standard deviation flags on MVP salinity at several depths for comparison MVP-TSG
C5: 0.20 ug/L - Standard deviation flags on MVP fluorescence at several depths for comparison MVP-TSG
C5: 0.04 psu - Standard deviation flags on TSG salinity during 2 minutes for comparison MVP-TSG
C5: 0.05 ug/L - Standard deviation flags on TSG fluorescence during 2 minutes for comparison MVP-TSG

////////// Processing //////////
------ Inter-comparison------
C1: Bias applied on transmittance
Constant bias correction: -10.650 %

C2: Bias applied on fluorescence
Constant bias correction: -0.200 ug/l
C3: Bias applied on dissolved oxygen
Constant bias correction: 0.000%
C5: Salinity bias statistics
Number of samples used (TSG) = 1
Median (bias)= 3.777
Mean (bias)= 3.777
Standard deviation (bias)= 0.000
Accuracy (bias)= 0.000
C5: Fluorescence bias statistics
Number of samples used (TSG) = 0
Median (bias)= NaN
Mean (bias)= NaN
Standard deviation (bias)= NaN
Accuracy (bias)= NaN
C5: Bias applied on salinity
Constant bias correction: 0.000 psu
C5: Bias applied on fluorescence
Constant bias correction: 0.000 ug/L

////// List of Casts //////

Cast	File_name	Date	Hour
1	1501003_0001.raw	03-May-2015	08:47:28
2	1501003_0002.raw	03-May-2015	08:52:58
3	1501003_0003.raw	03-May-2015	08:58:49
4	1501003_0004.raw	03-May-2015	09:07:39
5	1501003_0005.raw	03-May-2015	09:12:44
6	1501003_0006.raw	03-May-2015	09:19:57
7	1501003_0007.raw	03-May-2015	09:25:06
8	1501003_0008.raw	03-May-2015	09:30:39
9	1501003_0009.raw	03-May-2015	09:47:25

4. Data quality discussion

- Temperature uncertainty is in the order of 0.01°C or better. Inter-comparisons with the co-localised Rosette will provide validation for the MVP temperature data.

- Salinity uncertainty is in the order of 0.01psu (good Rosette inter-comparison) or better during periods of low vertical variability. However, the uncertainty can exceed 0.015psu during high vertical gradient.

- The sound velocity sensor worked well. Its measurements can be interpreted with an uncertainty in the order of 0.02m/s. The MVP sound velocity variation exactly corresponds to those calculated using the pressure, the salinity and the temperature. However, a constant difference persists between the MVP sound velocity values and values estimated from pressure, salinity and temperature (~0.3-0.4m/s). This difference is within the same order of magnitude and of the same sign through several legs and over several years. This might suggest that the method of estimating sound velocity is not suitable.

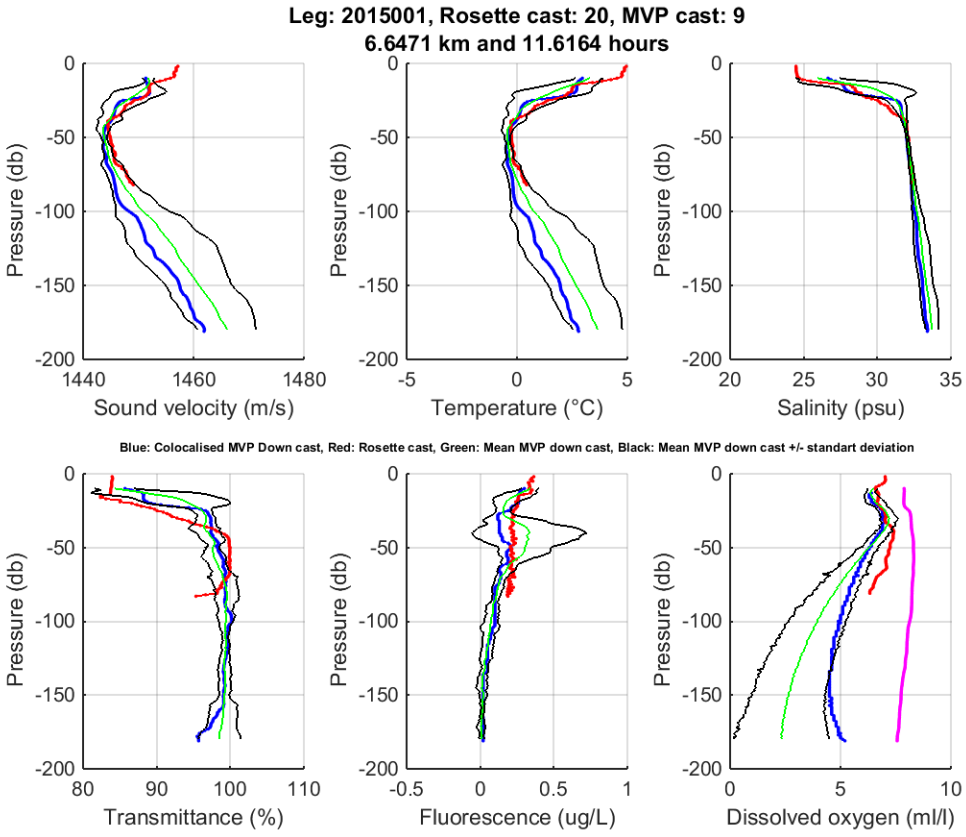
- Transmissometer provides very good results for this kind of use. The measurement noise is smaller than 0.1%.

- The dissolved oxygen sensor on the MVP is not well adapted for this kind of operation (free fall of the fish during down casts). The low response time of the sensor is not suited for these speeds of profiles. Furthermore, the sensor calibration is unstable and is only corrected on one point (from the CTD rosette comparison) for each transect. Therefore dissolved oxygen measurements must be used with caution and must be interpreted from a relative point of view and not in the absolute.

Annex 1: Rosette inter-comparison plot

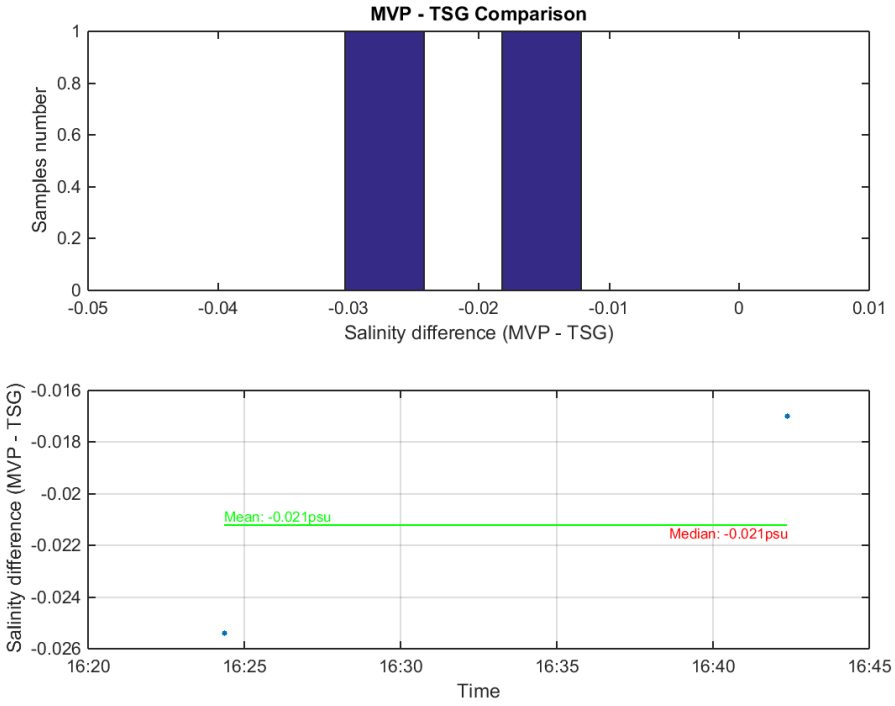
No CTD cast for transect 1 and 2.

- Transect 3

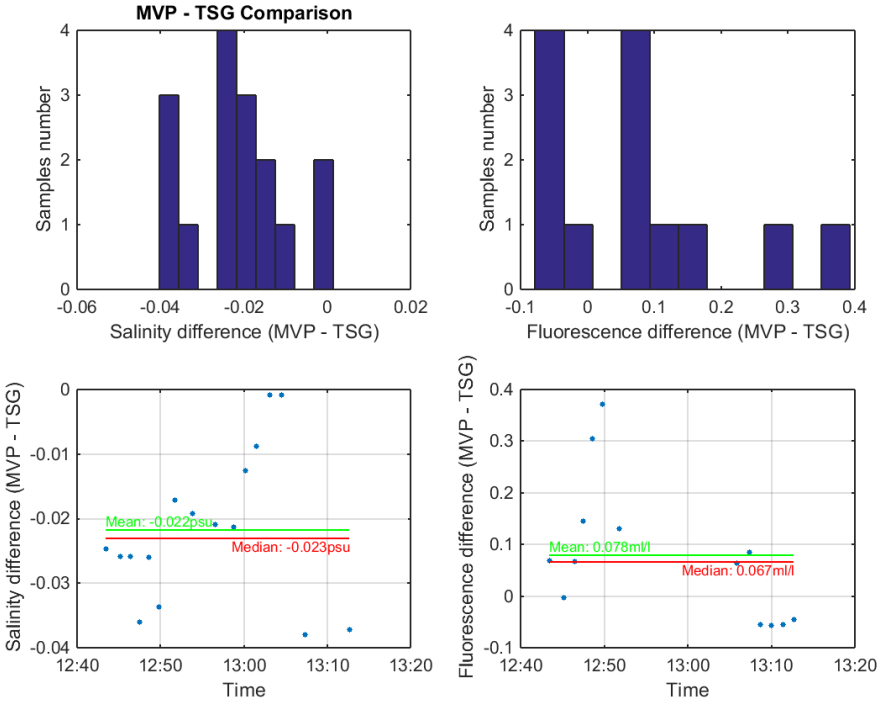


Annex 2: TSG Inter-comparison plot

- Transect 1



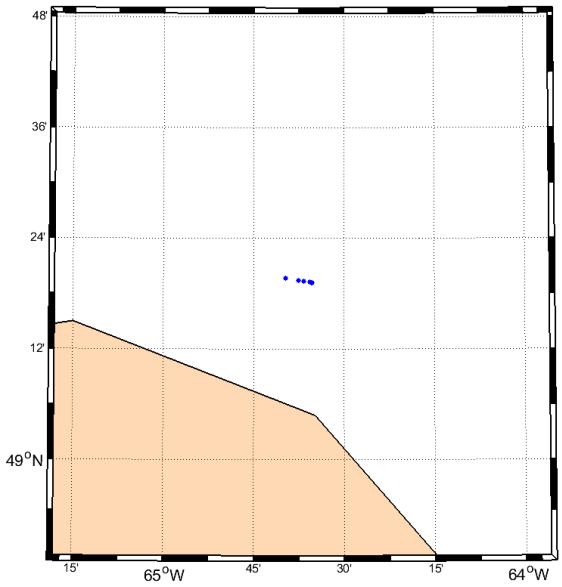
- Transect 2



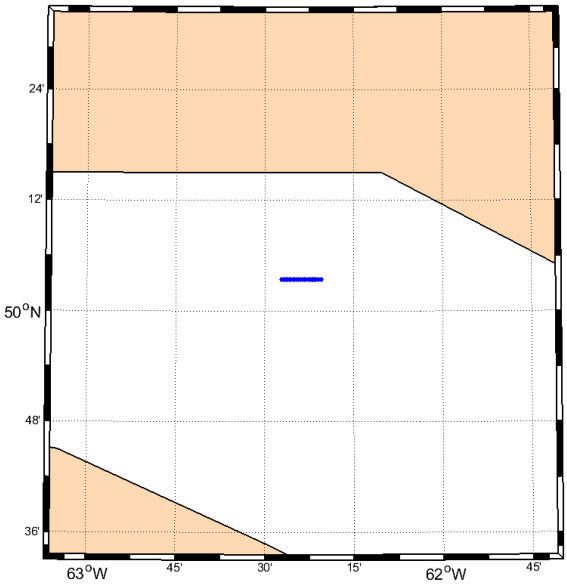
Annex 3: Mapping

Blue points are the MVP cast positions and red points the co-localised rosette positions.

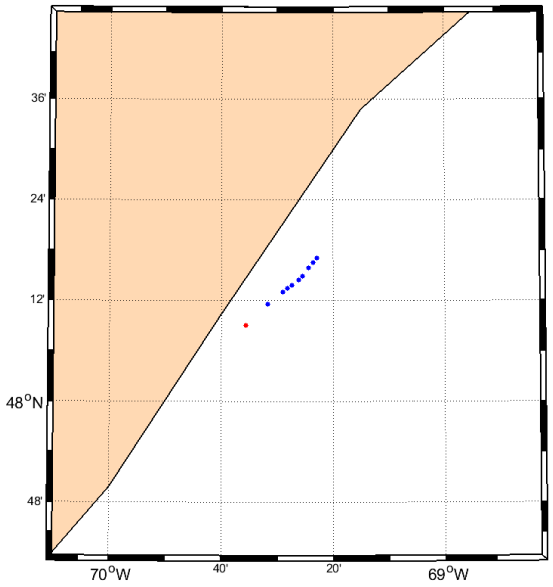
- Transect 1



- Transect 2



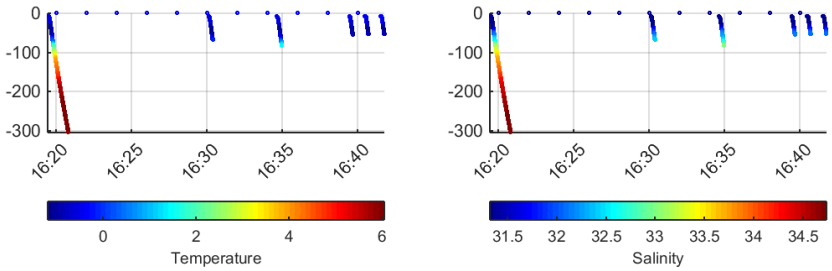
- Transect 3

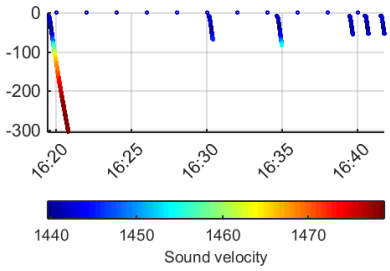


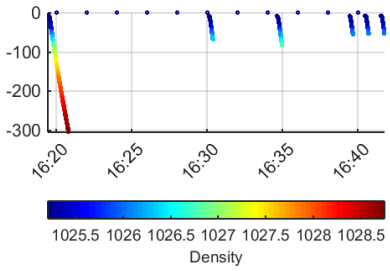
Annex 4: Scatter plots (MVP + TSG)

TSG data are the points represented near the surface.

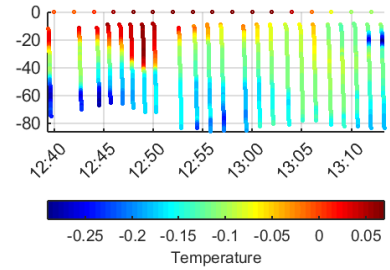
- Transect 1

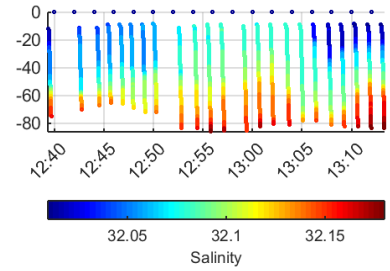


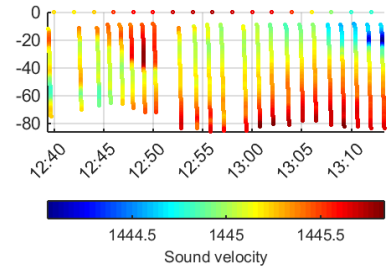


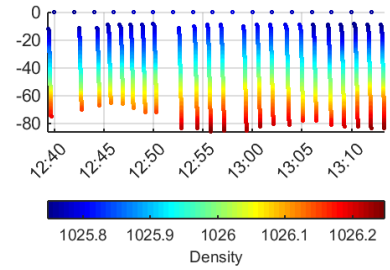


- Transect 2

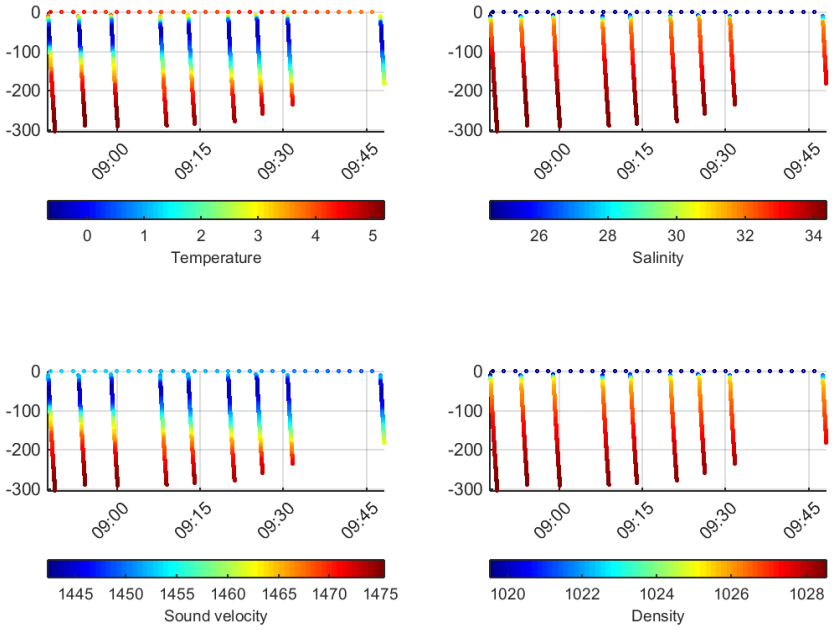




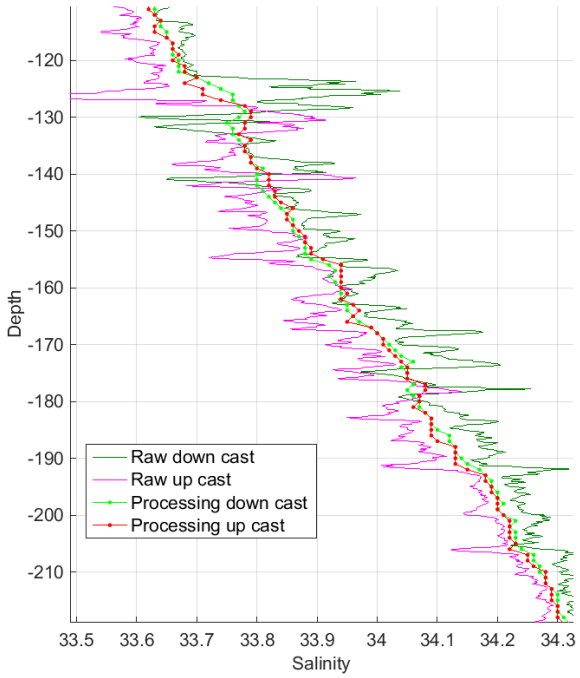




- Transect 3

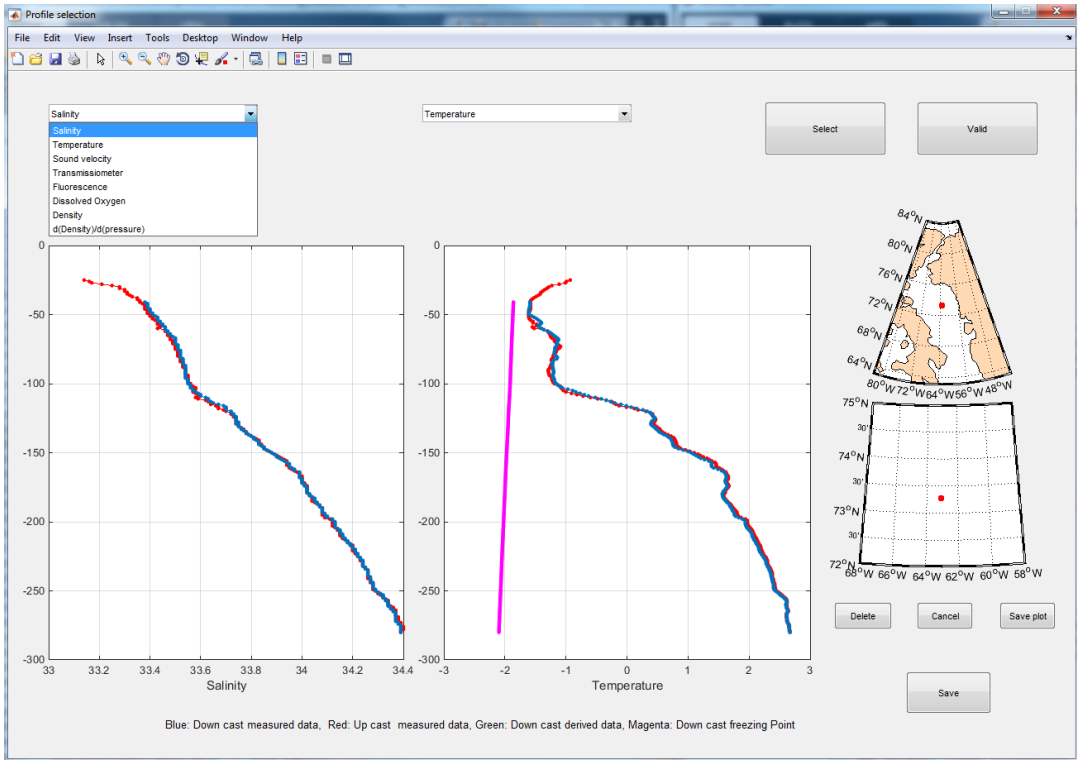

0
-100
-200
-300
09:00
09:15
09:30
09:45
0 1 2 3 4 5
Temperature
26 28 30 32 34
Salinity
1445 1450 1455 1460 1465 1470 1475
Sound velocity
1020 1022 1024 1026 1028
Density

Annex 5: Filter comparison

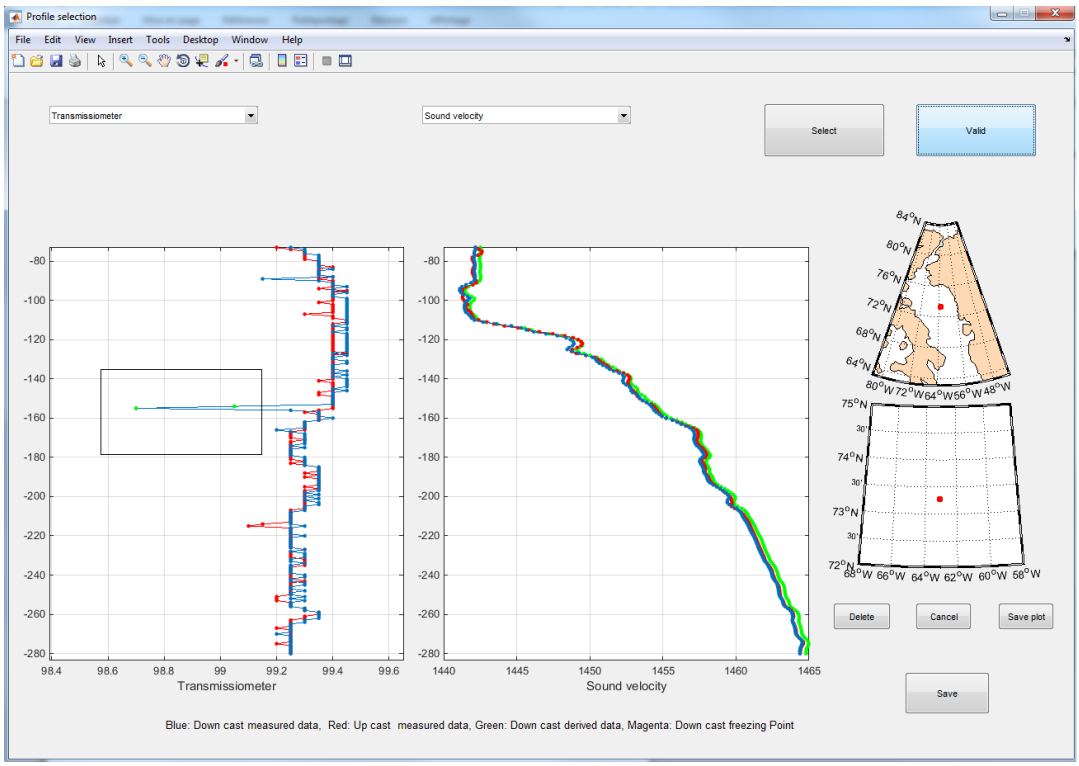


Comparison of raw and processed data after application of the Low pass filter and Align sensor filter.

Annex 6: Data visualizer



Selection of the variable to observe



Selection and flag of bad points